SINTEF REPORT

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TITLE

Final Report and White Paper: Potential Components of a Research Program Including Full-Scale Experimental Oil Releases in the Barents Sea Marginal Ice Zone

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ABSTRACT

In 2001, discussions with private industry and government agencies in the United States, Norway and Canada have suggested that a research program that involves laboratory and meso-scale research as well as a full-scale experimental oil release in the Arctic Marginal Ice Zone (MIZ) is timely. Primary interest appeared to be in evaluating alternative response options, developing potential new options where necessary and feasible, and in supplying data to strengthen model simulations of oil-ice interactions.

This report first summarizes the results of a preliminary workshop held October 15-16, 2001, at the MMS Alaska Regional Office in Anchorage. Based on suggestions from workshop participants, a set of proposed research and development tasks has been outlined. This suggested program could form the basis for more detailed discussions with future program partners.

Not addressed here are possibilities for coordination with other parallel activities, such as the assemblage of research goals and priorities being performed for the Oil Spill Recovery Institute in Cordova. Such coordination should be carried out through the Joint Industry Project (JIP) working group, and the eventual manager of any program resulting from the present effort.

The draft of this report was prepared in November 2001, but since the project "will not move forward in its present form", the time line has not been updated.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Modeling, Environment, Technology	Modellering, Miljø, Teknologi
GROUP 2	Decision support, Oil, Ice	Beslutningsstøtte, Olje, Is
SELECTED BY AUTHOR	Oil-ice interactions	Olje-is interaksjoner

Preface

Autumn 2001 US Minerals Management Service (MMS) and SINTEF tried to initiate a Joint Industry Project (JIP) on oil spill preparedness in Arctic waters, with activities to be centered around one or more full-scale oil-in-ice field experiments in the Arctic Marginal Ice Zone (MIZ) the coming years.

During a "Sponsorship Development Meeting" October 2001 in Anchorage, Alaska, a JIP working group was appointed to prepare a Request For Proposal (RFP) based on the discussions during the meeting. This working group was led by MMS, and had representatives from the industry and other potential sponsors.

The draft version of this report was prepared in November 2001, partly to sum up the meeting in Anchorage, and with some suggestions as input to the working group. Unfortunately the interest from the industry decreased during the weeks and months to follow, and the working group never finalized their mission. Recently SINTEF received the formal message about the proposed project from MMS: "It appears, that due to worldwide budget decreases for oil spill response research and a lack of a clear defined operational mission, that this project will not move forward in its present form."

As agreed with MMS, the report is left in the preliminary form prepared earlier, without updating the time line for the suggested activities. The ideas and suggestions put forward in this report are, however, still valid. We hope that they might be put to use in the future.

Trondheim, October 21, 2002

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1 Background

Recent discussions with private industry and government agencies in the United States, Norway and Canada have suggested that a research program that involves laboratory and meso-scale research as well as a full-scale experimental oil release in the Arctic Marginal Ice Zone (MIZ) is timely. Primary interest appeared to be in evaluating alternative response options, developing potential new options where necessary and feasible, analyzing alternative spill response scenarios, and in supplying data to strengthen model simulations of oil-ice interactions.

The Minerals Management Service (MMS) conducted a Sponsorship Development Meeting, October 15-16, 2001 in Anchorage, Alaska, to assess potential interest and establish an information base for a full-scale experimental oil release in the Arctic MIZ. The purpose of the meeting was to identify potential funding partners and to prioritize research needs and activities for a co-ordinated field experiment. Potential research partners were identified prior to the meeting (Table 1), and invited to participate in the 2-days of discussions. SINTEF Applied Chemistry prepared a White paper for MMS on the potential benefits from the experiments and conducted the meeting. The discussions and results of the Sponsorship Development Meeting are included in this final report.

*Table 1. Preliminary list of potential partners in an Arctic oil-ice interaction research program. The organizations that attended the meeting are in **bold**.*

Company	Category
USA:	
• **Alaska Clean Seas (ACS)**	**Private industry**
• **Cook Inlet Spill Prevention & Response, Inc. (CISPRI)**	**Private industry**
• Prince William Sound Oil Spill Recovery Institute (OSRI)	Private, non-profit organization
• **ExxonMobil**	**Private industry**
• **British Petroleum Exploration Alaska**	**Private industry**
• **Phillips Alaska**	**Private industry**
• Conoco	Private industry
• **State of Alaska, Department of Environmental Conservation (ADEC)**	**State government**
• State of Alaska, Department of Natural Resources	State government
• State of Alaska, Division of Governmental Coordination	State government
• **State of Alaska, Department of Natural Resources, Division of Oil and Gas**	**State government**
• **XTO Energy Inc.**	**Private industry**
• Special Assistant to the Secretary (Alaska)	State government
• **U.S. Minerals Management Service (MMS)**	**Federal government**
• **Alaska Science and Technology Foundation**	**State government**
• Alaska Oil and Gas Association	Private industry
• Alaska Chadux Corporation	Private industry
• **UNOCAL, Alaska Resources**	**Private industry**
• **U.S. Arctic Research Commission**	**Federal Government**

Company	Category
• U.S. Army Corps of Engineers, Alaska District	Federal government
• **National Oceanic and Atmospheric Administration (NOAA), Hazardous Materials (Hazmat)**	**Federal government**
• **University of Alaska Fairbanks (UAF)**	**Academia**
• Forest Oil Corporation	Private industry
• Marathon Oil Company	Private industry
• Cross Timbers Operating Co.	Private industry
• **U.S. Coast Guard, Marine Safety Office (MSO), Anchorage**	**Federal government**
• National Science Foundation, Office of Polar Programs	Federal government
• North Slope Borough	Local government
• Prince William Sound Regional Citizen's Advisory Council	Private, non-profit organization
• Cook Inlet Regional Citizens Advisory Council	Private, non-profit organization
• **Fairweather, Anchorage Office**	**Private industry**
• Exxon Valdez Oil Spill Trustee Council	State and federal governments
• Department Of Interior, Office of Environmental Policy and Compliance	Federal government
Canada:	
• Canadian Coast Guard	Federal government
• Conoco Canada	Private industry
• Alberta Energy, Oil Development Division	State government
• Environment Canada, Emergencies Science Division	Federal government
Norway:	
• **Norsk Hydro**	**Private industry**
• Statoil	Private industry
• Conoco Norway	Private industry
• Norwegian Pollution Control Authority (NPCA)	Federal government
• **University Courses on Svalbard (UNIS)**	**Academia**
• Norwegian Clean Seas Association (NOFO)	Private industry
• **SINTEF**	**Private, non-profit organization**
Sweden:	
• Swedish Coast Guard	Federal government
Finland:	
• Finnish Environment Institute	Federal government
Germany:	
• Hamburg Ship Model Basin (HSVA)	Private, non-profit organization
• Sonderstelle des Bundes zur Bekämpfung von Meeresverschmutzungen (Federal Marine Pollution Control Unit)	Federal government

2 General Program Goals

Overall program goals are to:

- Improve our ability to protect the Arctic environment against oil spills resulting from exploration, development, production and transportation activities.

- Provide improved basis for decision-making by responsible authorities
    - Approval of spill contingency response plans in Arctic areas
    - Facilitate removal of seasonal drilling restrictions where environmentally defensible

- Advance the state-of-the-art in Arctic oil spill response
    - Address key problems/scenarios faced by program partners
    - Demonstrate workable response options for different ice conditions and oil types
    - Define limiting conditions for alternate response strategies
    - Investigate and develop new response capabilities

Experiments and tests being considered include:

- Literature reviews as necessary to establish state-of-the-art.
- Laboratory
- Meso-scale (e.g. OHMSETT, SINTEF basin)
- Full scale field (Barents Sea ice field and ice edge; Svalbard shoreline and near shore fast ice)
    - Offshore multi-week
    - Offshore multi-month w/satellite tracking
    - Near shore and on shore multi-month / year

3 Priorities by Partner

3.1 US Minerals Management Service:

- Understanding oil-ice interactions;
- Broken ice: improve modeling;
- Dispersants in broken ice;
- OHMSETT testing of oil-in-ice: scaling factors, validation via field experiment;
- Oil-ice interactions first order algorithms for weathering model;
- Freeze-up as well as broken ice; (break-up is different from broken ice, etc.)
- Mechanical, dispersants, and burning options in various ice conditions;
- Multiple oil types
- Data management for future use (see ACS comments)

3.2 US Arctic Research Commission:

- Burning
- Mechanical cleanup
- Applied research; use of lab, meso-scale, and field, as appropriate
- Oil-ice interactions
- Dispersants

3.3 State of Alaska, Department of Environmental Conservation (ADEC):

- Mechanical response: limitations and potential enhancements
- Ice management (e.g. creation of open leads to corral the oil)
- Limits of burning
- Evolution of slick in ice; monitoring as a response option until oil exits ice field
- Oil on ice
- Breakup is primary interest

3.4 National Oceanic and Atmospheric Administration (NOAA):

- Physics and chemistry of oil-ice interactions
- Weathering and transport
- Information management in oil spill response
- Monitoring
- Presentation methods / graphics

3.5 Norsk Hydro:

- Development of set of scenarios
- Transport
- Exploration
- Production
- Which scenarios can we respond to today?
- What do we need to develop to respond to the other situations?

3.6 ExxonMobil:

- Response options (start in lab; validate in field / meso-scale)
  - Burning
  - Dispersants
  - Mechanical
- Prediction of transport and weathering (secondary importance)

3.7 UNOCAL, Alaska Resources:

- Oleophilic rope skimmers (realistic performance tests) to achieve optimized use
- Other mechanical alternatives

3.8 Cook Inlet Spill Prevention & Response, Inc. (CISPRI):

- Dynamic ice conditions: weathering, behavior of oil
- Oil on solid rotting ice (pans and ”jumbled-up rafters”)
- Ice-sediment-oil interactions
- Effect of release conditions on response options
- Underwater versus surface (air-water, ice-water, air-ice) releases
- Oil temperature
- Batch versus continuous releases

3.9 US Coast Guard:

- Response operations
- Overall and windows of effectiveness of alternatives
- Oil-ice interactions; effects on response alternatives
- Fate of oil in ice (new ice, broken solid and rotten ice)
- NEBA analysis in response decision-making

3.10 Alaska Clean Seas:

- Need to use existing information; not re-invent the wheel;
- (Contributed comments by ADEC): Oil spill cleanup
- Conclusion of MORICE tests
- Improve ability to pump cold water emulsions
- Breaking emulsions to improve pumpability

3.11 University of Alaska Fairbanks (UAF)/Akvaplan-NIVA (Tromsø, Norway):

- Biological studies
- Sympagic and epontic (on and in ice) fauna and flora
- Planktonic organisms
- Fish
- Benthos and sediments
- Oil, dispersants, burning impacts
- Conditions analogous to Alaskan environments (nearshore and offshore)
- Seasonal and recovery issues
- Selected organisms; lab experiments
- Birds, marine mammals
- Geological and chemical studies
- Processes and products of weathering
- Entrainment of oil in sea ice during freeze-up

4 Summary of Issues Raised

- Effectiveness of dispersants in broken ice
  - Dispersant and oil characteristics
  - Ice, wind and wave conditions
- Mechanical response options
- Complete testing of MORICE skimmer
- Evaluate options for oil on ice
- Burning options
  - Ignition and burn effectiveness: oil type, weathered state, relevant ice conditions
- Monitoring as a response option (e.g. until conditions favor another action)
- Understanding oil-ice interactions for improved modeling
- Oil weathering and transport; broken and shore-fast ice; freeze-up and break-up
- Alternate release conditions (batch, continuous, surface, sub-surface)
- Development of ”typical” or “key” spill scenarios to guide R&D and contingency planning
  - Transport, exploration, production: Which scenarios can we respond to today?
  - What do we need to develop to respond to the other situations?
  - Seasonal considerations (weather, currents, biology)
  - Ice and oil types
  - Release types (underwater, surface, batch, continuous)
- Remote sensing
- Biological effects
- Multiple oil types, spanning a range of characteristics
- Studies over time scales of days to years
- Data management for future use (not re-inventing the wheel)
- Applied research; use of lab, meso-scale, and field, as appropriate
- Bio-remediation

5 Possible Program Elements

The following report sections focus on separate tasks or projects that may be undertaken during the program. Each project may span more than one year, depending on the nature of the work.

The University Courses on Svalbard (UNIS; http://www.unis.no/) conducts annual expeditions into the Arctic ice fields. Activities during these excursions cover a range of academic and scientific studies, and allow for the possibility of arranging smaller additional field studies at comparatively low cost. Because the logistics associated with ship hire are already in place, UNIS can facilitate the planning and execution of smaller field trials.

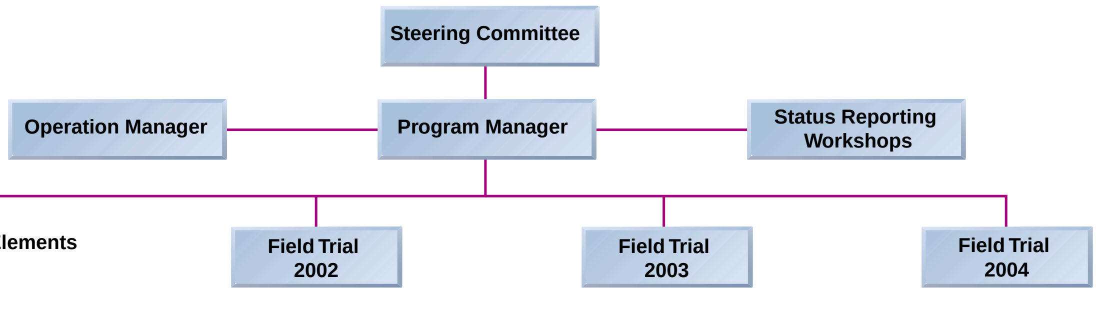
The potential program elements that follow are the result of suggestions received from participants at the Anchorage workshop. In some cases two or more suggestions that were very similar have been combined into one. In other cases, a suggestion that included several separate aspects may have been divided among several elements. Overall, we have attempted to retain the full spectrum of suggested activities, recognizing that the Joint Industry Project (JIP) development work group may decide not to include all elements in an eventual request for proposal.

5.1 Program Management, Time Line and Activity Inter-Dependencies

Program coordination and management will be an on-going activity throughout the life of the program. SINTEF is prepared to manage the program for the JIP Steering Committee, or a JIP member can take on this responsibility. The following figures outline the primary interdependencies among program components.

Not addressed here are possibilities for coordination with other parallel activities, such as the assemblage of research goals and priorities being performed for the Oil Spill Recovery Institute in Cordova. Such coordination should be carried out through the JIP working group, and the eventual manager of any program resulting from the present effort.

Following is an approximate time line for the activities to be carried out within each program element. We assume approximately bi-annual workshops for planning, status reporting, and coordination purposes.



Scenario Development:	Preliminary →	Review / Update →	Final
Burning:	desk, lab, small scale →	desk, lab, full scale →	desk, lab, full scale
Dispersant Tests:	desk, lab, meso-scale →	meso-scale, full scale →	meso scale, full scale
Mechanical:	desk, meso-scale →	desk, meso scale, full scale →	desk, meso, full scale
Monitoring:	? →	available technologies →	available technologies
Environmental Measurements:	(UNIS) →	(SINTEF) →	(SINTEF)
Water Soluble Component	preliminary field →	lab, field →	lab, field
Oil Spreading:	preliminary field →	field →	field
Oil Weathering:	preliminary field →	field →	field
Long Term Weathering:	preliminary field (?) →	field →	field
Model Validation:	desk, preliminary field →	desk, field →	desk, field
Biological Effect:	desk, lab, preliminary field →	lab, field →	lab, field
Biodegradation:	desk, lab →	lab, field →	field
Data Management:	desk →	desk →	desk
	2002 →	**2003** →	**2004**

Figure 5.1 Approximate time line for the activities.

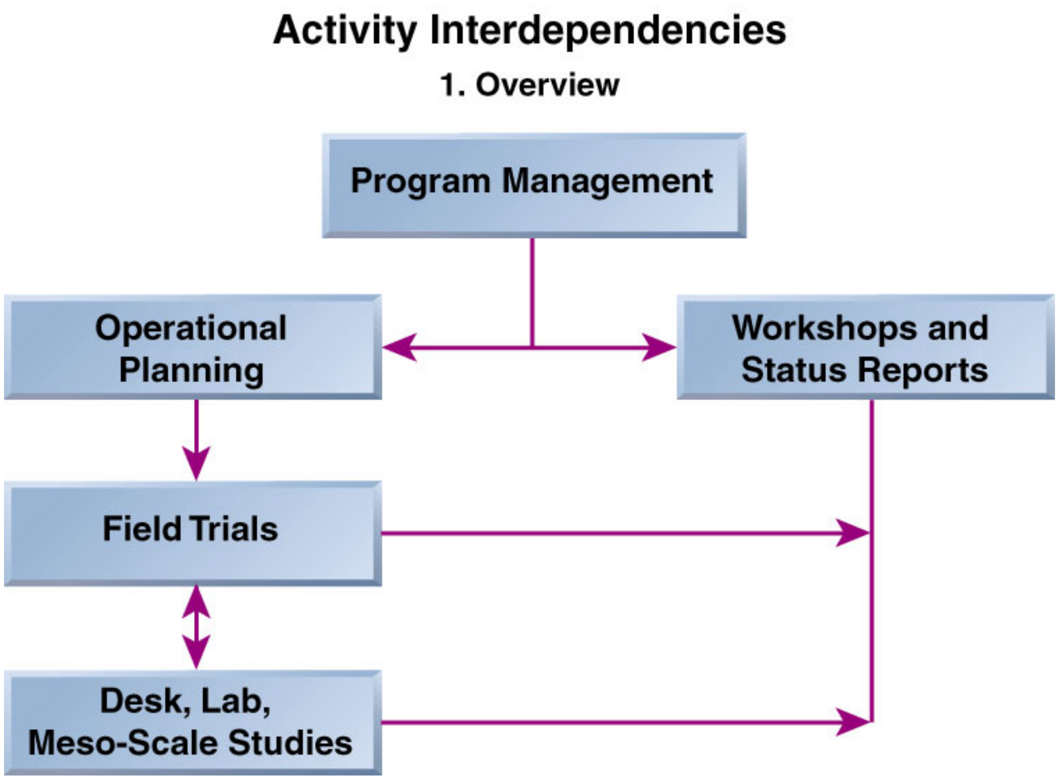


Figure 5.2 Overview of Activity Interdependencies.

5.2 Field Trial Operations: Preparation and Management

<u>Research Need</u>: Each excursion into the field will require planning and coordination of all operational aspects, to maximize the probability of success for all program components. SINTEF assigns a single experienced operations manager to fulfill this role.
<u>Objective</u> To coordinate the planning, mobilization, execution, and de-mobilization of each field trial to achieve smooth operation and successful completion of all tasks.
<u>Justification</u> The complexity of the proposed field trials requires a dedicated operations manager. The expense of such trials clearly justifies the assignment of an operations manager focused on achieving success for as all tasks.
<u>Preliminary scope of work:</u> • Arrange ship time, number of berths, transportation in the field • Coordinate with Program Manager with regard to costs and priorities • Schedule operations to take advantage of synergies and weather windows, and avoid conflicts •
<u>Deliverables</u> Operations plan in advance of each field trial

5.3 Workshops for Program Definition, Coordination, and Status Reporting, and Management

Research Need: The program steering committee and program manager need regular oversight of activities, and direct access to key research personnel. Project leaders need regular access to leaders of related projects to achieve both coordination and symbiosis.
Objective To facilitate information exchange, reporting of project status, generation of solutions to problems, and coordination among program components.
Justification Interdisciplinary workshops provide an opportunity to coordinate components within a complex program. Experience reflects that such workshops can also generate new solutions and ideas to existing problems, through cross-fertilization among different fields of study. Workshops for which formal status reporting to research peers is required also provide an impetus to maintain or exceed project time plans and goals. The importance of this latter factor should not be under-estimated.
Example scope of work (depending on actual program definition): 1. Spring workshop, 2002, Svalbard (Detailed presentation of plans for each project in the program; Discussion of project inter-dependencies; Reporting and assessment of field work 2002; Planning for 2003, 2004; Steering committee meeting 2. Early winter workshop, 2003, Trondheim (Project status reports; Planning for field work 2003; Steering committee meeting) 3. Autumn workshop, 2003, Trondheim (Project status reports, with focus on 2003 field work results; Specification of program for 2004; Steering committee meeting) 4. Spring or autumn workshop, 2004,Trondheim or Svalbard (Final reporting of all activities; all deliverables due; Steering committee meeting) 5. Production of summary video (CNN?)

5.4 Pre-field-trial in the Marginal Ice zone - May 2002

Research Need: Perform a limited expedition to the actual area in the marginal Ice Zone (MIZ) already in spring 2002. This expedition will function as a pre-activity to the more comprehensive expedition in 2003. To reduce cost this expedition could be performed in connection to already scheduled activities in this area. One such possible expedition is described below. As a part of a university course AT-311 "Fate and modeling of pollutants in the Arctic" at UNIS (http://www.unis.no/studies/technology/at-311.htm) a field expedition to this area between Bear island and Hopen will be arranged in May 2002. This expedition will last for a week and we will measure ice properties and collect samples for PCB analysis (water, ice/snow, plankton, shrimp, fish and birds). We will also perform two smaller oil spills (barrel-sized).
Objective Give key personnel within the program the opportunity to familiarize with the conditions in the experimental area. This knowledge will be important input to the planning (both logistical and scientific) for the main expedition in 2003.
Justification We could extend this already scheduled UNIS expedition (May 2002) with a week to include additional activities. Time and logistical cost could be reduced by holding the vessel in MIZ and flying personnel in and out with helicopter.
Preliminary scope of work: Several small-scale activities could be performed during such an add-on expedition. These could be: • small-scale testing of equipment or concepts (e.g. for releasing the oil) • ice mapping • small-scale scientific activities (e.g. combined weathering/burning experiment) • Background sampling (baseline studies)
Deliverables Input to the further planning of the main expedition in 2003
Time schedule with milestones 01.01.2002: Decision concerning vessel hire

5.5 Realistic scenario development to guide contingency research and development planning for Arctic waters (2002-2003)

Research Need: Determine sufficiency of current clean-up technology to meet the criteria set by the oil companies and authorities. Identify scenarios requiring additional R&D to reduce environmental consequences, or for which monitoring is the best initial response.
Objective Modeling of selected Arctic oil spill scenarios with realistic data input (spill rates, ice conditions, oil types oceanographic/environmental-data) and compare expected environmental impact with/without present oil spill cleanup technology.
Justification Exploration in Arctic waters (Northwest Russia, Sakhalin, Alaskan waters) will require comprehensive, state-of-the–art spill contingency plans drawing on the best available methods and equipment for oil spill response. Many potential spill scenarios may be quite similar for different areas. A coordinated effort should help to achieve consistent, high quality response plans for partners. At the same time, the use of similar scenarios and response methods should give significant cost reduction through elimination of redundancy.
Preliminary scope of work: • Develop scenarios on potential oil spills from exploration drilling and transport in Arctic environments. Use typical weather, ice, current, biological, oil type, release type conditions, or apply stochastic modeling to determine dimensioning (e.g. 95%) worst-case scenarios. • Areas of interest are: 1. Sakhalin 2. Northwest Russia 3. Barents Sea 4. Alaska North Slope 5. Caspian Sea 6. Cook Inlet 7. Ports and harbors • Transport, exploration, and production scenarios may be considered. • Apply modeling to find whether appropriate "accept criteria" are fulfilled. • Decide which scenarios can be realistically created and tested in the field, vs. in OHMSETT, or smaller meso-scale or laboratory facilities. • Determine which scenarios can only be monitored with today's response alternatives, and which can be actively dispersed, burned, or recovered. • Suggest R&D goals for improved response capabilities.

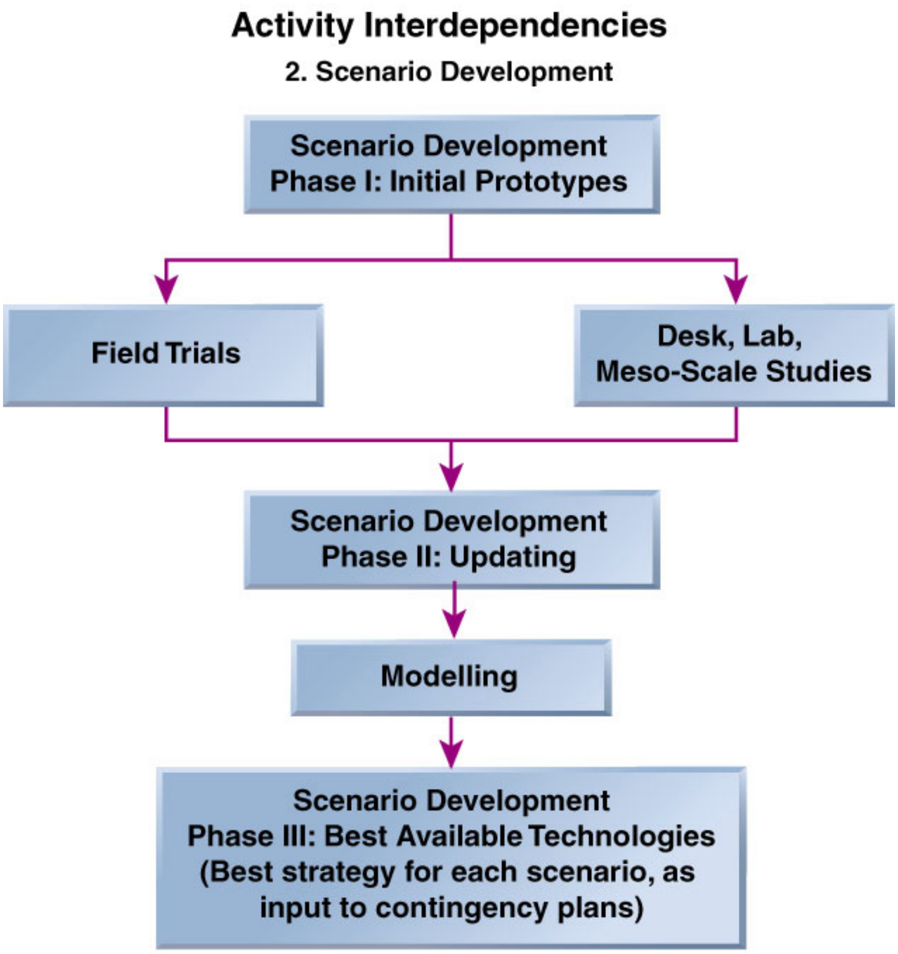


Figure 5.3 Scenario Development.

***In situ* Burning (2002 – 2004)**

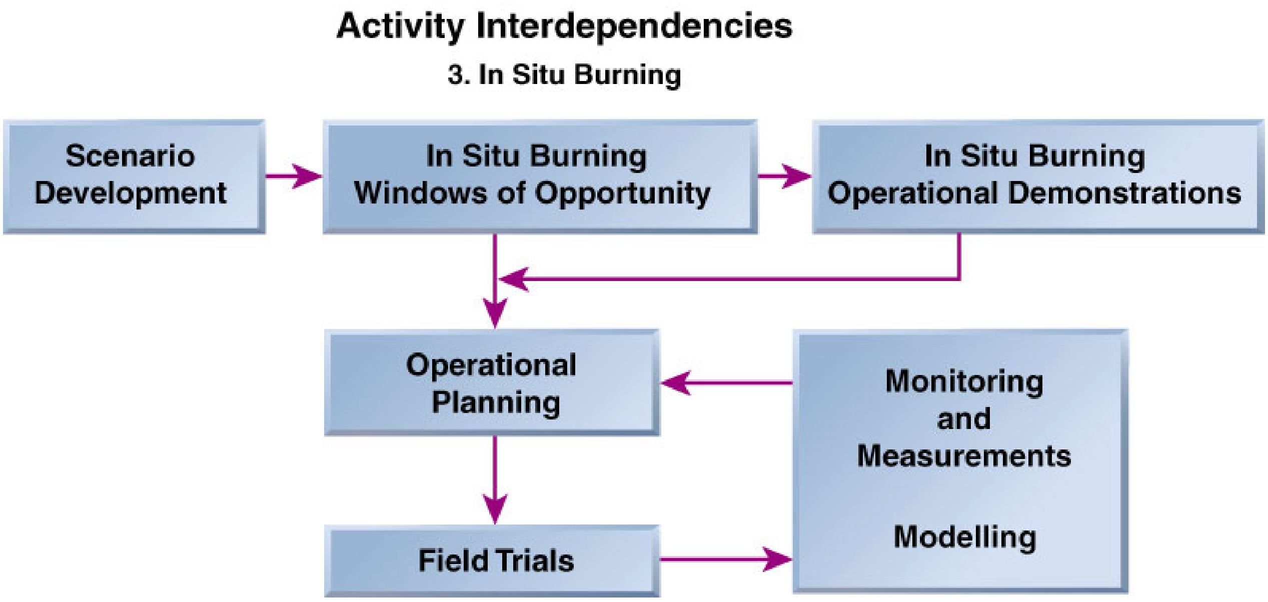


Figure 5.4 In Situ Burning.

5.5.1 Operational *In situ* Burning in Broken Ice Conditions

<u>Research Need</u>: Operational *In situ* Burning in Broken Ice Conditions.
<u>Objective:</u> The objective is to conduct full-scale operational *in situ* burns in broken ice conditions. The focus should be on the types of broken ice typically found in the nearshore areas of the Alaskan Beaufort Sea where oil exploration activities are taking place or are planned. Several Oil Spill Response Organizations (OSROs) have purchased active boom systems (MSRC is one).
<u>Justification:</u> The technology and techniques to conduct *in situ* burns (ISB) have matured in the past few years. Most ISB projects have been conducted in small-medium test tanks. The NOBE experiment was a research not operational exercise. There are certain tactics and technique that can only be accomplished through an open water exercise. Information from these experiments will be used to make justifiable, scientific-based decisions on the suitability of *in situ* burn packages for the intended operating environment.
<u>Preliminary scope of work</u>: New types of fire resistant booms (actively cooled) have been developed and tested in the past few years. None have been tested in Arctic conditions. Conduct ISB experiments with actively cooled booms in ice infested waters to determine their performance. Testing both inside and outside the ice edge could be included. One day to test and evaluate each boom.
<u>Prerequisite tasks:</u> Contact active boom manufacturers and see if they are willing to donate sections of their actively cooled fire resistant booms for the experiment. The draft American Society of Testing and Materials (ASTM) testing ISB guidelines (5-hour burn test) would be used in the evaluations. Relevant data from Burning Windows of Opportunity Task.
<u>Deliverables</u>: Boom performance data report, pictures, videos.

5.5.2 Identify window of opportunity for *in situ* burning

Research Need: Identify the "window of opportunity" for ignition and efficient burning of oil spills in Arctic waters.
Objective: Establish how the physical/chemical properties of oil, the oil weathering/emulsification and environmental factors will affect the ignitability and burning efficiency of both crude oils and refined petroleum products for *in situ* burning under Arctic spill scenarios.
Justification: Improvement of the ignition techniques and of fire proof booms will increase the window of opportunity for *in situ* burning. As demonstrated through several larger programs in North America and Norway, *in situ* burning has the potential to be an effective oil spill response technique in Arctic and remote spill scenarios. However, operational feasibility may be difficult to determine without actually trying to burn. We propose to establish a standard methodology to predict the "window of opportunity" for *in situ* burning. The essential element is the development of a laboratory ignitability assessment test. Results from laboratory experiments to be compared with results from meso-scale systems and verified through field experiments. The data from these tests and experiments should be used with existing oil weathering models to predict the window of opportunity for the use of *in situ* burning for a variety of oil types.
Preliminary scope of work 1. Establish "State-of-the-art" for *in situ* burning under Arctic conditions 2. Theoretical studies on methods for ignitability and burning efficiency tests under realistic conditions (e.g. methods like Pensky-Martens, Cleveland Open Cup and Cone calorimetric) 3. Improve existing methodologies to enhance the ignitability temperature 4. Establish and calibration of laboratory test system 5. Perform systematic ignitability and burning efficiency laboratory tests with different oil types and refinery products at different weathering degrees. 6. Testing of selected oils in meso-scale burning systems. 7. Verification of laboratory data in field experiments 8. Development of algorithm to describe and predict the burning of oils as a function of their physical/chemical properties, degree of weathering and distribution in the ice field.
Deliverables: Draft guideline for *in situ* burning under Arctic conditions. Ignitability data report.

5.6 Dispersants in Arctic Conditions (2002 – 2004)

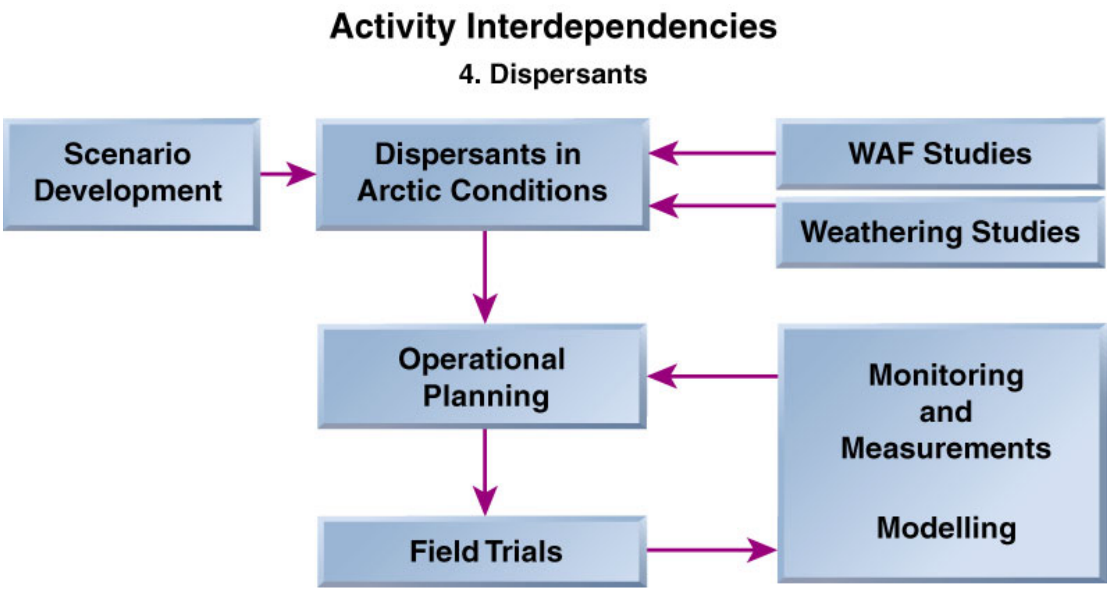


Figure 5.5 Dispersants.

<u>Research Need</u> The potential usefulness of dispersants in Arctic conditions has not been demonstrated by earlier limited laboratory and field trials.
<u>Objective:</u> To establish a better understanding for the potential in operational use of dispersants in various spill scenarios under Arctic conditions. To define the limiting cases for applicability of dispersants in cold and/or ice covered waters. Explore the capabilities of dispersants to effectively disperse various oils in (1) cold water, (2) in the presence of brash and slush ice, and (3) with different levels of mixing energy. Relate laboratory mixing energy to sea states observed in the field
<u>Justification:</u> Earlier studies carried out in Norway (ONA report 1995 / AKUP report 1996) conclude with: " that use of dispersant can be a suitable response method, either as an independent response method or in combination with e.g. mechanical recovery, to a number of scenarios in Arctic waters – both in open water and in ice coverage up to around 50%", i.e.: • Application from aircraft /helicopter /boat on oil spill in open water (outside the ice edge) • Application in relative open ice from helicopter or boat (use of artificial mixing energy?) • Application in pond of melted ice or oil in high coverage, preferable by helicopter. This could have the positive influence upon enhanced dispersion rate when the oil is drifting out in open / turbulent water There is, however, a need to establish a better documentation through systematic experiments both through small-scale lab-studies, controlled basin studies as well as full-scale operational dispersion application in the various environmental conditions. If effective, dispersant use can remove much more oil from the water surface than mechanical methods. In addition, dispersants can often be applied in conditions where mechanical recovery would not be possible.
<u>Preliminary scope of work:</u> 1. Literature review - "State-of the art" 2. Perform systematic dispersant effectiveness studies in standardized lab-methodologies in cold water and ice conditions (with different oil types / weathering degrees / energy states)

3. Perform specific mechanism studies to investigate the leaching potential of dispersants out from a treated oil-film to underlying water (both laboratory and meso-scale flume basin studies with different oil types / weathering degrees / energy states)
4. Perform selected dispersant effectiveness studies in Ohmsett-tank (cold water and ice conditions
5. Operational dispersant application in relevant conditions in the Barents Sea (Full-scale trial, with /without use of artificial mixing energy)
6. Study the effect of long term weathering /storage of oil treated (spiked?) with dispersants frozen in ice and the effect when the oil reaches open water

5.7 Mechanical Response Options (2002 – 2004)

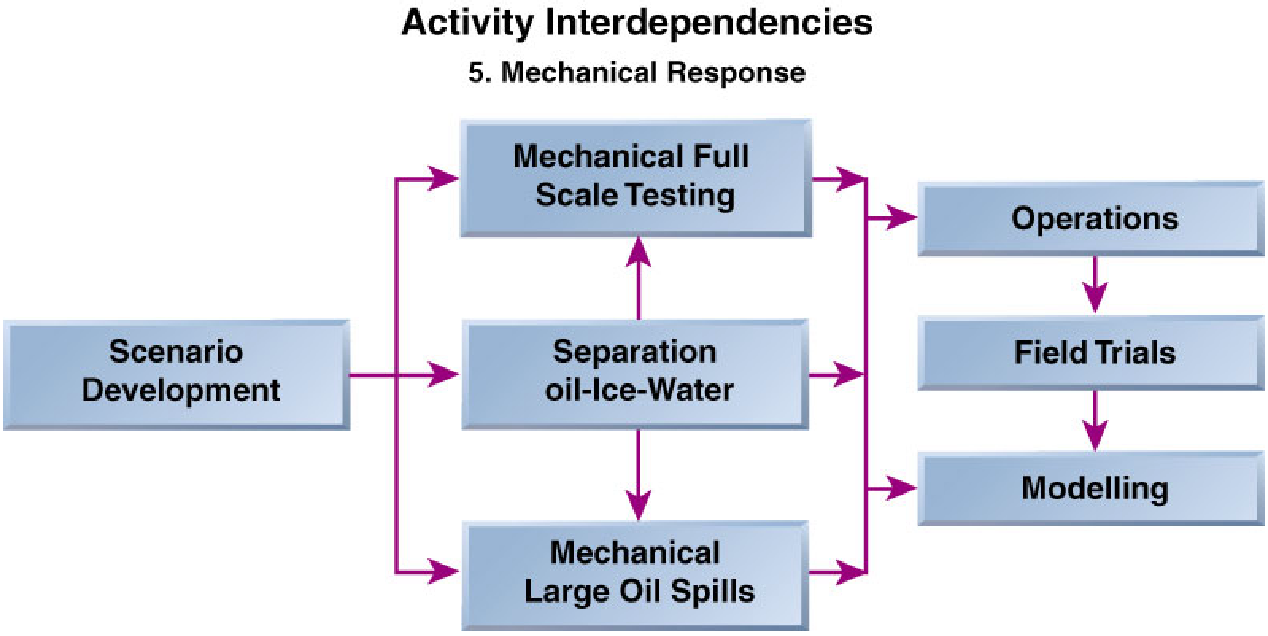


Figure 5.6 Mechanical Response.

5.7.1 Full-scale testing of oil spill equipment

Research Need: Obtain more knowledge regarding operational effectiveness of oil spill response equipment designed or modified for use in Arctic waters.
Objective: Perform meso-scale and full-scale testing of existing oil spill equipment.
Justification: Testing of oil spill equipment specially designed or modified for use under Arctic conditions is complicated to do in test tank facilities. Similar to open water conditions, final verification should be performed under more realistic conditions with respect to temperature and ice conditions. The added complexity of a recovery operation in ice compared to open water conditions (like low temperature, reduced access to oil, large amounts of ice in recovered product, icing/freezing of components and recovered product) makes it extremely difficult to evaluate the effectiveness of a recovery operation in ice-infested waters. Demonstration projects will improve the understanding of the important processes, and lead to improved techniques and tactics.

Preliminary scope of work:
• Available equipment - state of the art/earlier Arctic experience
• Meso-scale testing of existing equipment in oil and ice:
  o MORICE concepts
  o the most important elements of the mechanical response tactics developed for use in broken ice conditions at the Alaska North Slope, such as
    ▪ containment booms
    ▪ deflection of large ice away from booms (ice management)
    ▪ ice deflectors in front of recovery units
    ▪ Brush-pack side collectors (LORI)
    ▪ rope mops
    ▪ transfer of recovered product from recovery unit to temporary storage

5.7.2 Mechanical recovery to respond to large oil spills in broken ice

Research Need: Mechanical recovery to respond to large oil spills in broken ice
Objective Develop mechanical response technologies that will make it possible to recover large quantities of oil in dynamic broken ice of various floe sizes (not just small ice). Develop mechanical response method with features to improve the oil encounter rate and recovery capability and deal with ice of various sizes.
Justification All current technologies are limited by ice size and/or lower recovery efficiencies in cold/ice. Techniques that overcome these limitations are desired.

Preliminary scope of work:
It is very likely that the window of opportunity for mechanical recovery of oil-in-ice could be increased significantly, although it is difficult to imagine that the limitations associated with ice size and environmental conditions could be overcome entirely:
• Review state-of –the –art techniques
• Define ice and spill scenarios to be used in development, avoid being over-ambitious
• Brainstorming, developing ideas
    • Identify limiting factors
    • Design or re-design as necessary to overcome limitations of existing alternatives
    • Scale up existing equipment that is promising
    • Put together existing concepts in new ways
    • Look for ideas in other businesses where handling of large volumes/weights are essential (mining, farming, road construction etc.)
    • As a first step to develop new technologies, identify ways to demonstrate or study the essential elements of the ideas
  • Build prototypes
  • Demonstrate concept at meso-scale (e.g. OHMSETT)
  • Demonstrate applicability to field situations

5.7.3 Separation of oil from ice and water

Research Need: Separation of ice from oil and water, prior to storage if possible.
Objective: Separate ice and water from recovered product during oil in ice recovery, in order to minimize storage capacity needs and to avoid having solid ice formation in storage containers.
Justification: During recovery of oil in ice-infested waters, considerable amounts of ice (and water) could be recovered together with the oil. Prior to storing recovered product, as much ice and water as possible has to be separated to reduce the necessary storage capacity and to avoid creating massive ice in the storage. This is one of the most important problems to solve, or at least reduce.
Preliminary scope of work Lab experiments: o Prepare mix of oil and ice and water o Test different ways to enhance separation of oil from ice (and water), for instance: • warm water flushing, combined with washing while conveying oil/ice (mini LGB) • hot bath where oil/ice mixture is fed through (avoid as much melting as possible to maintain the heat in the water • heating mixture of oil/ice with a burner (propane, kerosene) to increase temperature and reduce viscosity • addition of emulsion breakers/dispersants? • breaking ice into small ice pieces (maybe 3-5 cm in diameter), get access to pockets of oil encapsulated in the ice, prior to separation o Design, construct and test pilot plant under real conditions

5.8 Bioremediation (2002 - 2004)

Bioremediation experiments on Arctic shorelines can be carried out on Svalbard at Svea. Since this subject was only briefly mentioned at the workshop, no more detailed suggestions have been prepared here. SINTEF has extensive expertise in shoreline bioremediation studies at field and laboratory scales, should this be an area of interest for the Joint Industry Project.

5.9 Monitoring (2002 – 2004)

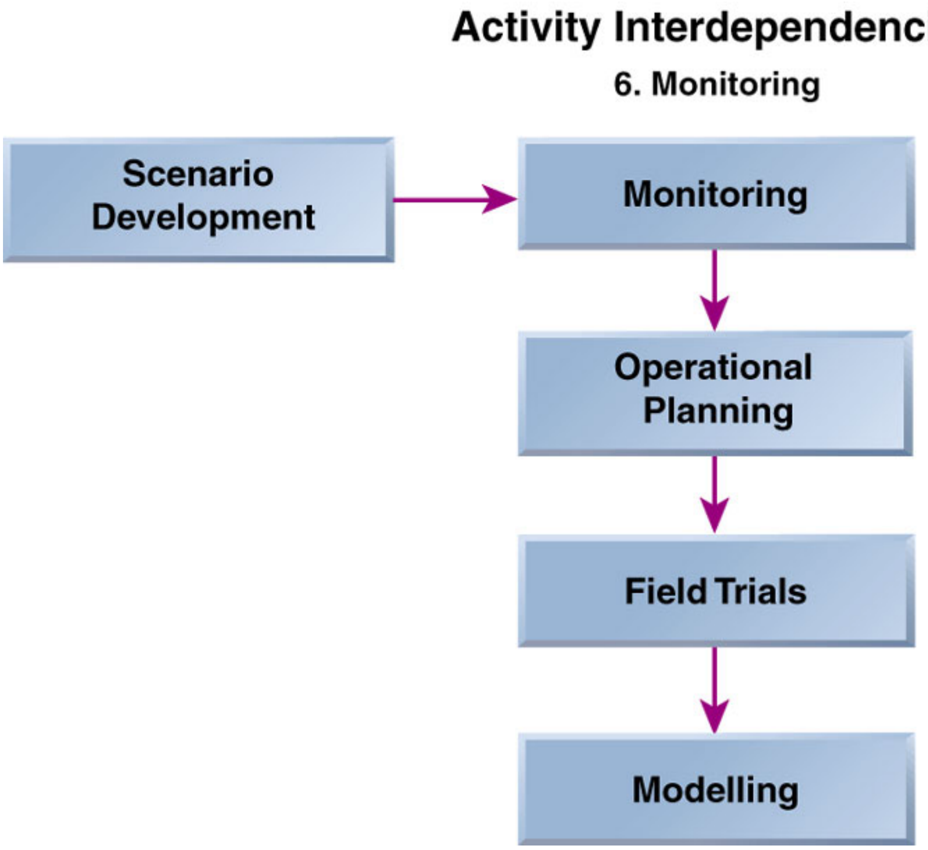


Figure 5.7 Monitoring.

Research Need: Available detection and monitoring equipment for oil spills in ice is not well established, and the potential for this equipment is uncertain. Non-invasive remote monitoring or tracking technology to determine the location and spread of oil under ice would be a significant step forward.

Objective: Test available equipment for monitoring oil-in-ice; develop technology to detect/track oil on, under and in ice, and to demonstrate such technology in the field.

Justification: Little knowledge exists regarding the fate of oil spills in broken ice with respect to drifting and spreading. Present monitoring technology needs to be tested in near realistic scenarios. The need for and potential in modifications/development should be established.
Available remote sensing technologies (e.g. SLAR, UV, IR, microwave) can to some extent detect oil between ice and on ice, but not during unfavorable conditions (like under even a very thin layer of snow), and not underneath the ice. In scenarios with a large spill under ice or with considerable water currents relative to the ice, the location of the oil has to be determined in order to facilitate response activities.
There are also needs for improvement of

- *in situ* detection methods of dispersed oil and dissolved oil components in the water column below the ice
- sampling methodology, both in the water column, and in the ice

Preliminary scope of work:
The following activities should be considered:

- Available equipment - state of the art/earlier Arctic experience
- Near realistic testing of existing equipment and techniques
- Identification of strengths and weakness, suggestion for improvements based on test experiences

Sampling in, under and beneath the ice should be coordinated with sampling and monitoring of biological activity.

5.10 Physical and Chemical Process Studies for Modeling and Effects Estimation (2002 – 2004)

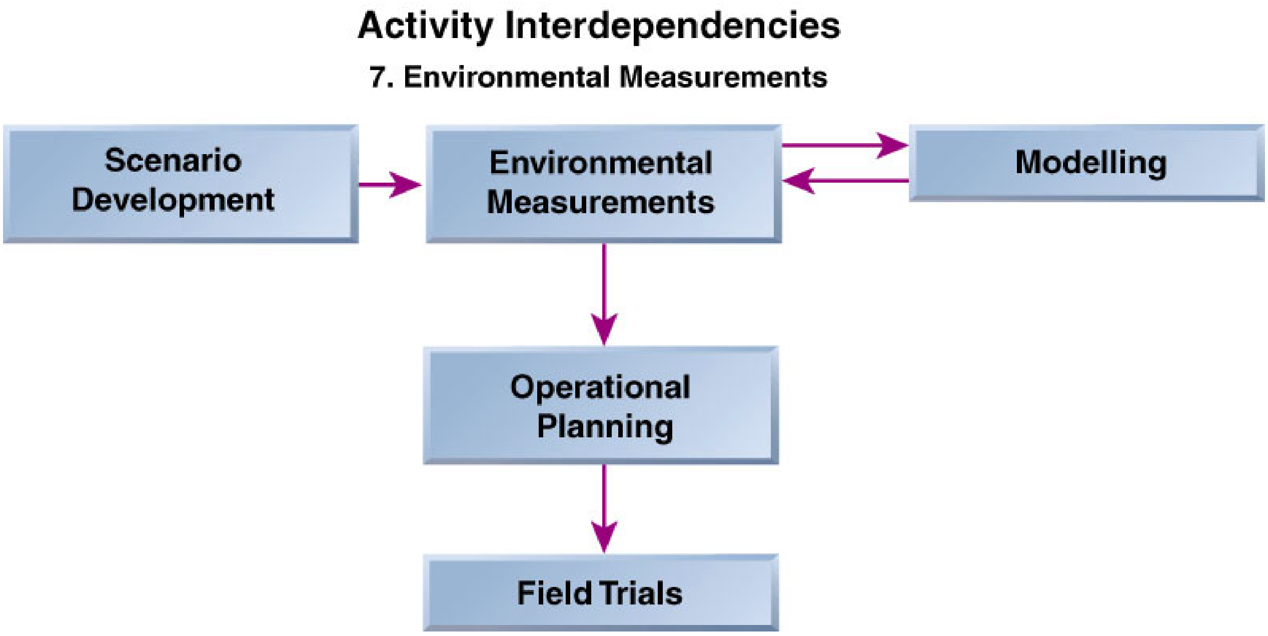


Figure 5.8 Environmental Measurements.

5.10.1 Measurement of key environmental variables in the field

Research Need: Not primarily a research task; rather a support task to supply background information for many other physical, biological, and chemical studies
Objective To provide time-series measurements of winds, currents, air and water temperatures, ice parameters, and other environmental data (e.g. water column sediment loads), as required by other tasks
Justification Provides necessary primary data to virtually all elements of the program. Essential for all modeling tasks.
Preliminary scope of work: Deployment of appropriate measurement sensors as defined during design of the overall program, and as necessary for individual projects: • wind • currents • ice drift • ice parameters (thickness, snow cover, type) • air, water temperatures • wave conditions •

5.10.2 Characterization of water soluble components from Arctic oil spills

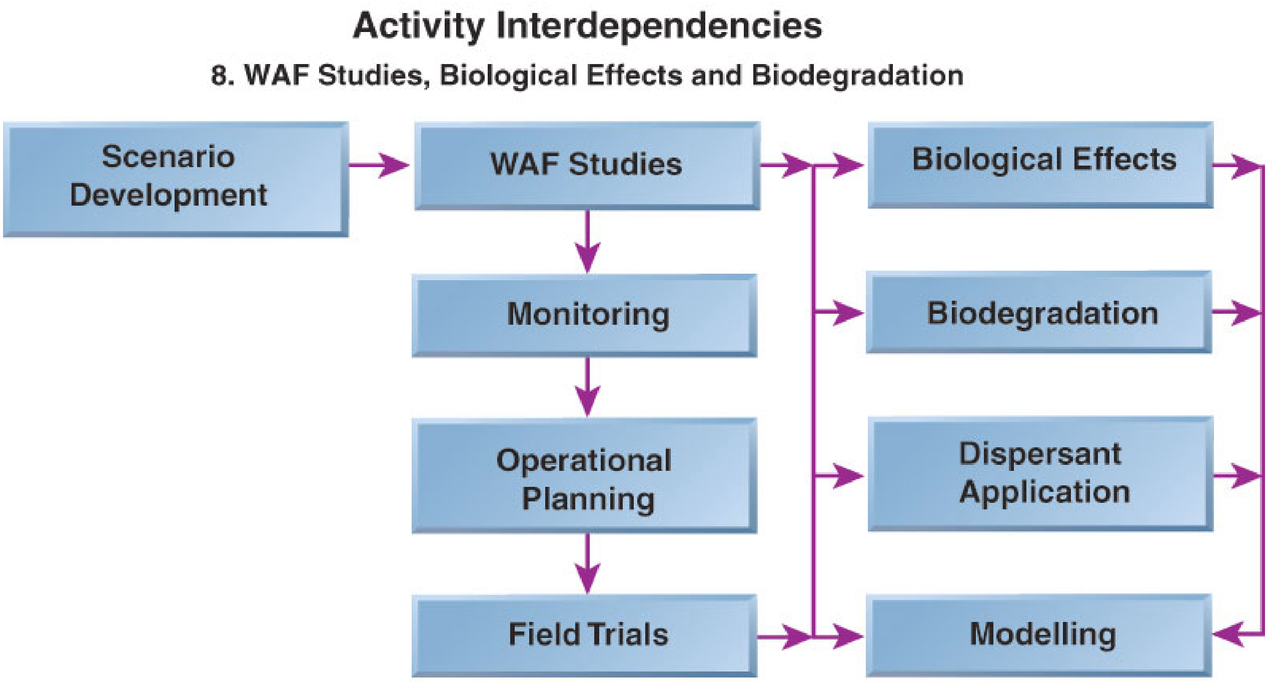


Figure 5.9 Water Accommodated Fraction (WAF) studies, Biological Effects and Bioremediation.

<u>Research Need</u>: The fate of toxic water-soluble oil components (BTXs, PAHs and different acids) or the water accommodated fraction (WAF) have been extensively studied in the labs at e.g. UNIS and SINTEF. However, laboratory experiments at low temperature and especially comparative laboratory-field experiments are lacking to verify important laboratory findings.
<u>Objective</u> Verify earlier findings regarding WAF from different oil types at low temperatures by performing a comparative laboratory and field experiment.
<u>Justification</u> Toxic water-soluble components from an Arctic oil spill trapped in ice will be bio-available for the vulnerable Arctic ecosystem. The concentrations of these components when oil is trapped in the ice and the possible exposure to the marine organisms is not known, but is of significance for Environmental Risk Assessment for Arctic oil exploration. This project will characterize (measure composition and concentration) of the WAF from different oil types under Arctic conditions (low temperature and varying ice conditions). This project is coupled to another proposed project from UNIS (UNIS 2) and will be performed by our PhD students supervised by our professors and personnel from SINTEF.
<u>Preliminary scope of work:</u> Laboratory experiments using international accepted procedures for testing WAF from oil types at Arctic spill scenarios will be performed. The main findings from the laboratory investigation will be verified trough field experiment. • Laboratory studies (varying temperature, ice conditions, oil types and weathering degrees) Verifying field experiments (selected variables)

5.10.3 Transport and spreading of oil in ice

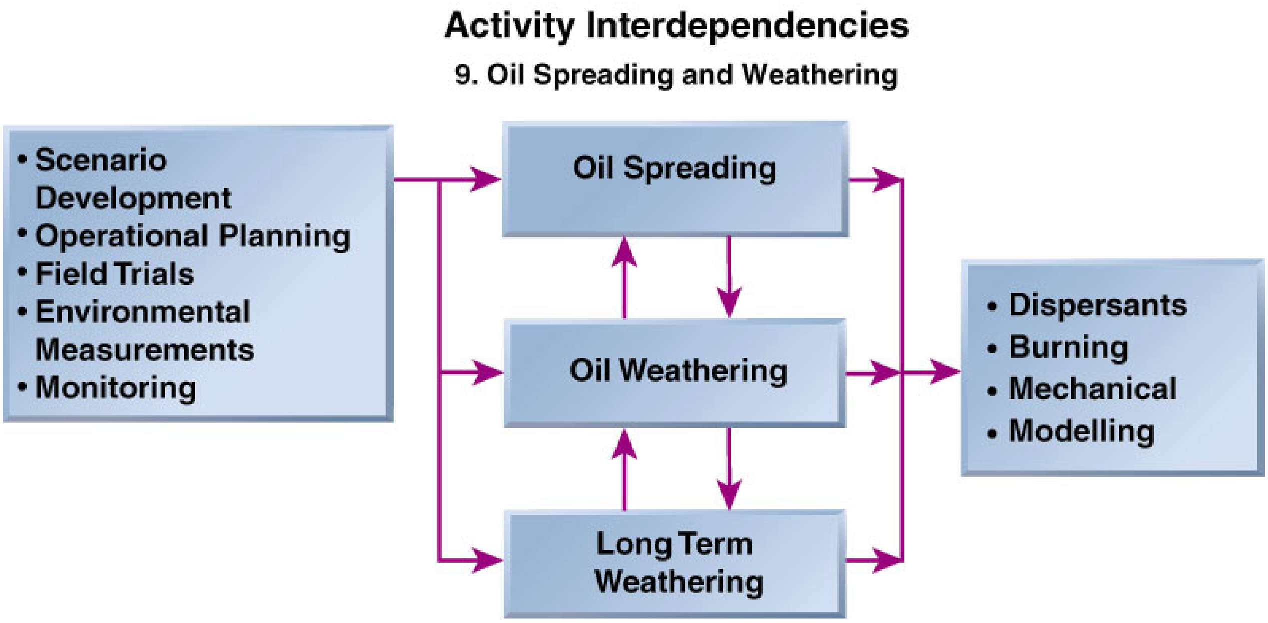


Figure 5.10 Oil Spreading and Weathering.

<u>Research Need</u> Determine transport and spreading of oil in ice. Quantify effects of oil, ice, and snow properties, and environmental parameters.
<u>Objective</u> Quantify the transport of different oils as a function of physical/chemical properties in porous media (Ice and snow) under different environmental conditions. Establish algorithms for these processes for numerical models.
<u>Justification</u> After an accidental oil spill under Arctic conditions with snow and ice, the interaction between the oil and the frozen porous media will depend on a large number of parameters including the oil type and weathering degree, the physical properties of the porous media and the environmental factors. Information on these processes will be important in a decision making process to choose the best response strategy, both within a short- and long-time window.
<u>Preliminary scope of work</u> 1. "State-of-the-art" for transport of oil and petroleum products in frozen porous media 2. Establish laboratory methodology which simulate the main environmental parameters 3. Systematic testing of transport of oil in snow and ice; • Oil types and weathering degrees • Porous frozen media with different characteristics • Environmental parameters • Freeze-up and break-up periods 4. Testing of selected combination parameters based on results from activity (3) under controlled conditions. Short and long term fate and effects. 5. Verification of laboratory data in field experiments 6. Establishing algorithms for transport of oil in frozen porous media

5.10.4 Oil weathering, validation, enhancement of weathering algorithms

Research Need Collect physical and chemical measurements of oil weathering and use these to validate and enhance oil weathering algorithms for oil weathering models.
Objective The objective is to collect basic research data on evaporation, dispersion, spreading, and other weathering parameters in the marginal ice zone. This data would then be used to enhance and modify or develop new algorithms of oil weathering in and on ice. The work aims to provide an experimental basis for the enhancement or development of algorithms in analytical models.
Justification Oil spill weathering models are used in National Environmental Policy Act (NEPA) analysis as well as Oil Discharge Prevention and Contingency Plans (ODPCPs). The results of these models are used to estimate impacts in NEPA analysis as well as pre-planning for oil spills. A modest amount of work in the field was done more than a decade or two ago developing first order physics regarding oil weathering in ice. However, the field data required by models is scarce, of poor quality or non-existent. Additional studies have continued in the laboratory in the late 1980's and 1990's. Currently the oil-ice interactions are ad-hoc methods with no consensus on the preferred solutions. The sophisticated measurement techniques currently available would enable precise measurements regarding oil evaporation, spreading and dispersion in ice as well as on ice.
Preliminary scope of work • Measure emulsification, evaporation, dispersion, spreading, slick thickness, and oil composition in an ice field • Use these data to develop a database on oil weathering in ice fields for use in model validation • Use these experimental data in concert with other oil-ice weathering data to validate and enhance or develop new algorithms of oil weathering in ice. Some of this work should be done with both high and low pour point oils. Liberty crude would be an example of a high pour crude with pour point above environmental temperatures.
Prerequisite tasks Collect and analyze data on weathering of oil in ice, including but not limited to evaporation, emulsion, dispersion, spreading and slick thickness.
Dependant tasks Develop a dataset from the experimental data for use to validate weathering algorithms and oil weathering models in the presence of ice. Validation and enhancement of development of new oil weathering algorithms.
Deliverables Database or experimental data set of oil weathering parameters in ice fields Validated or enhanced oil in ice weathering algorithms Inclusion of new algorithms in the SINTEF oil weathering model that are validated by the field results.
Time schedule with milestones To be developed, likely multi-year
Tentative amount of work and costs Multi-year

5.10.5 Long term weathering of oil spills in ice

Research Need: Little knowledge exists regarding long-term (i.e. > months rather than days) weathering and biological effects of oil spills in Arctic waters.
Objective Increase the knowledge concerning long-term weathering (spreading, evaporation, emulsification, dispersion, and biodegradation) and biological effects of oil spilt in Arctic waters.
Justification Little knowledge exist regarding long term weathering of oil spills in broken ice both with respect to weathering processes and biological effects. Previous experiments have often had a time frame of days and have not taken long-term effects into account. "Long term" should here be regarded as a time frame at least of several months.
Preliminary scope of work: The following activities should be considered: • Weathering properties of oil spills in ice-infested waters • Focus on decay rates and spreading of oil in ice • Focus on possible biological effects of oil components Focus on the biologically productive and important ice-edge

5.10.6 Testing and verification of oil-in-ice drift and fate models

Research Need Testing and verification of oil-in-ice drift and fate models.
Objective To provide a comprehensive data set on drift and fate of oil spilled in cold water and sea ice for testing and verification of oil-in-ice models. Determine degree of oil/ice interaction with respect to oil drift as a function of ice coverage, ice characteristics, and wind and current velocities.
Justification Oil drift and fate models play an important role in environmental risk assessments prior to exploration and production in new prospective oil fields. As these activities move into Arctic waters, oil drift modelers are faced with new challenges. In order to succeed in extending present oil drift and fate models into Arctic waters, they must have data available for testing hypothesis and assumptions on oil behavior in cold water and ice.
Preliminary scope of work • Prepare data set describing ambient conditions (wind, currents, air/sea temperatures, ice coverage, ice types) and observations of oil (location, spreading, degree of weathering, partitioning between ice and water etc.) for use by modelers • Perform trajectory calculations and compare with observations • Report on procedures and parameters producing best fit performance of the models
Deliverables • Technical report describing instrumentation and observational methods, general findings and preliminary analysis of data (comparison with state of the art models). • Data set describing ambient conditions (wind, currents, air/sea temperatures, ice coverage, ice types) and observations of oil (location, spreading, degree of weathering, partitioning between ice and water etc.) for use by modelers

5.11 Biological effects and accumulation (2002-2004)

Research needs: Determination of biological effects and accumulation of oil-in-ice and melting oil-infested ice on relevant Arctic organisms of the major tropic levels. Determine kinetics of dissolution of water-soluble components from dispersed oil, as a function of temperature.
Objective: - Quantify the impact (effects and accumulation) of oil-in-ice conditions on relevant Arctic organisms, including sympagic (ice algae, ice fauna) planktonic (phytoplankton, zooplankton), nektonic (e.g. Arctic cod), and benthic organisms. - Quantify the impacts on relevant Arctic species from melting ice infested with oil. - Determine the distribution of water-accommodated fractions (WAF) and oil droplets on selected organisms in the ice and during ice melting - Determine the kinetics of dissolution of water soluble components from dispersed oil
Justification: Toxic WAF and oil (emulsions, dispersions) trapped in ice, and during melting of the ice edge, will be bio-available for the Arctic ecosystem. The bio-availability and uptake mechanisms differ between organisms and tropic levels, resulting in response variations to oil exposure. Only fragmentary knowledge exists on the effects of oil on sympagic organisms. Accumulation patterns are expected to vary between pelagic and sympagic organism due to the different oil weathering processes. Toxicity and accumulation data are thus required for representative species of the three dominant components of the Arctic food web system; the primary producers (phytoplankton), the primary consumers (crustaceans) and the secondary consumers (fish), and with selected organisms representing both pelagic and sympagic organisms.
Preliminary scope of work: - Laboratory based studies with relevant marine Arctic organisms (representing both sympagic, pelagic, and sediment habitats) performed with ice conditions and with melting ice - Data achieved through experiments: Oil and WAF characterization under ice conditions, effects (mortality, inhibitory, behavior changes) on selected species and on communities, accumulation in single species and across tropic levels (bio-magnification), effects on primary production, abnormal behavior, EROD liver activity (Fish) and PAH components in fish bile - Determination of dissolution rates of water soluble oil components as a function of temperature - Verification by field experiments
Prerequisite tasks: - Toxicity and accumulation studies of different WAF and oil types with algae and crustaceans performed at moderate temperatures at SINTEF - Studies of WAF from different oil types at low temperatures (earlier MS-studies) at UNIS - Studies of dissolution rates from crude oils at SINTEF
Deliverables: Report describing the effects and accumulation of oil components (droplets and WAF) from Arctic spills on marine ice edge organisms
Time schedule and milestones: Laboratory studies – 2 years (2002-2003) Field studies/reporting – 1 year (2004)

5.12 Biodegradation of oil compounds in the ice edge (2002-2003)

<u>Research needs:</u> Data on biological degradation of water-accommodated fractions (WAF) and dispersed oil droplets in ice edge zone are required, both for estimation of fate and depletion rates, and to determine persistent compounds most likely exposed to vulnerable Arctic fauna. Depletion should be determined both in ice-infested oil and after ice melting. Adsorption characteristics of both dispersed oil and dissolved oil components to ice are important to understand chemical and biological processes of oil in ice. Important layer of bacteria and algae in ice edge is a very important parameter when considering both biodegradation and adsorption characteristics of oil in Arctic environment.
<u>Objective:</u> - Determine depletion of oil compounds in ice infested oil and WAF and after ice melting, using natural Arctic seawater as microbial inoculum. - Relating the depletion to changes in toxicity to selected marine organisms - Describe adsorption characteristics of dispersed oil and dissolved oil components to ice and layer of bacteria/algae in the ice edge.
<u>Justification:</u> Biodegradation is related to the complexity of the oil compounds and to the bioavailability, e.g. when a compound is distributed between a WAF and an oil phase, the degradation is more rapid in the WAF than in the oil. It is also assumed that biodegradation decreases significantly with reduced temperature, but experiments with psychrophilic (“cold-loving”) bacteria thriving in Arctic waters have shown significant degradation rates at very low water temperatures. Whether any biodegradation of frozen oil compounds appears is largely unknown. Further, it is important to describe the adsorption characteristics of dispersed oil and dissolved oil components to ice and layer of bacteria/algae in the ice edge. This is a process, which affects the rate of biodegradation in the Arctic environment.
<u>Preliminary scope of work:</u> - Oil droplets and WAF (generated by accepted methods) from relevant oils and weathering conditions - Laboratory studies with natural Arctic seawater performed with ice conditions and with melting ice - Data achieved through experiments: Degradation rates and persistence of oil compound groups (aliphatic and aromatic compounds) in the oil droplets and WAF (e.g. ice algae, Arctic crustaceans) - Describe adsorption characteristics of dispersed oil and dissolved oil components to ice and layer of bacteria/algae in the ice edge in designed laboratory experiments - Relating degradation to acute toxicity of selected ice or cold water organisms - Verification by field experiments (Spitzbergen) relating degradation to hopane biomarker compounds
<u>Prerequisite tasks:</u> - Degradation rates and definition of persistent oil compounds in WAF and oil droplets from experiments with natural seawater performed at SINTEF - Studies of WAF from different oil types at low temperatures (earlier MS-studies) at UNIS

<u>Dependent Tasks:</u> - Development and testing of (long term) weathering models
<u>Deliverables:</u> Report describing the degradation rates of oil and WAF compounds, as well as defining persistent oil compounds after oil spills in the Arctic ice edge.
<u>Time schedule and milestones</u>: Laboratory studies – 1 year (first year) Field studies/reporting – 1 year (second year)

5.13 Data Management (2002 – 2004)

<u>Research Need</u> Collect data in a standard format such that it is available to present and future research efforts
<u>Objective</u> Create a database, organize and collect exiting data, make the data available to oil spill researchers generally (internet website)
<u>Justification</u> Oil-ice interaction studies have been carried out for at least 30 years, and at considerable expense. Data that has been generated is generally difficult to access, and is therefore essentially lost to the research community. Making as much of this data available as possible will help to advance the state-of-the-art at relatively little cost. The data will provide the basis for development and testing of oil spill model algorithms, and for development of oil spill contingency and response plans and actions.
Preliminary scope of work A. Data base definition, with (open ?) Internet access (2002) B. Historical literature and data collation and entry (2002) C. Establishment of procedures for logging of data from other on-going and future projects (2002) D. Logging of program data (2002 – 2004)

6 Conclusions

Both the workshop in Anchorage and subsequent collation of information concerning research needs point to a research and development program necessarily spanning at least two years. The mounting of one or more full-scale field trials itself requires many months of planning and preparation to maximize the probability of success. In addition, some of the most promising research areas, such as the use of dispersants in Arctic conditions, require preliminary laboratory and/or meso-scale studies for successful demonstration of the concept at full scale. Furthermore, it is difficult to address a wide variety of alternative issues, such as different oil types, release, and environmental conditions, during one and the same experimental time period. Thus it appears useful to leave open the possibility for a multi-year study plan, with built-in flexibility.

Preliminary outlines have been prepared for projects focused on the key issues raised by potential program partners. The integrated program might progress approximately as follows:

Year 2002
- Spring: kick-off with preliminary burning trial in the marginal ice zone, and planning workshop on Svalbard
- Summer-Fall-Winter: selected literature, laboratory, and meso-scale tasks; planning of the 2003 field work

Year 2003
- Early Winter: Workshop for finalizing of field trial plans
- Spring: Full scale field trials
    - Multiple releases (control slick, surface and subsurface releases, different oil types)
    - Equipment testing
    - Dispersant testing
    - *In situ* burning
    - Demonstration of remote sensing capabilities
    - Etc.
- Summer-Fall-Winter:
    - Data analysis
    - Reporting

Year 2004:
- Early winter: Status and plans workshop
- Spring: potential second field trial to address situations not covered in 2003 (e.g. other oil types, other release and environmental conditions)
    - Multiple releases (control slick, surface and subsurface releases, different oil types)
    - Equipment testing
    - Dispersant testing
    - *In situ* burning
    - Demonstration of remote sensing capabilities
- Completion of all projects and deliverables

The challenges associated with the constellation of experiments discussed here are many and varied, but use of experienced personnel and organizations will provide the best available assurance of success.

- End -